U. S. Department of Energy • National Energy Technology Laboratory

SCNG Newsletter

Strategic Center for Natural Gas (SCNG) Communicating Results Fall 2003

Contents

Direct FuelCell® Considered "Ultra-Clean" Technology

NETL's 27-year partnership with FuelCell Energy has certainly paid off in commercial success: in the first half of 2003, FuelCell Energy installed a hydrogen-powered 250 kW fuel cell in downtown Los Angeles, and the Direct FuelCell® (DFC300A) power plant has earned three prominent certifications that will reduce the time and cost for installing fuel cells, and help speed their acceptance into the energy market.

In February 2003, FuelCell Energy (FCE) DFC300A was certified for grid interconnection with the investor-owned electric utilities under California's "Rule 21" standard, the largest fuel cell to date to be certified. In May 2003, FCE's DFC300A power plant was certified to meet the American National Standards Institute (ANSI) products safety standard for stationary fuel cell systems. Three days later, FCE announced that its sub-megawatt Direct FuelCell® power plant was certified to meet the California Air Resources Board's (CARB) stringent new distributed generation emissions standards for 2007. By meeting this standard, the Company's sub-megawatt DFC power plant is categorized as an 'ultra-clean' technology, exempting it

Courtesy of FuelCell Energy.

American National Standards Institute (ANSI)

The American National Standards Institute (ANSI) is a private, non-profit organization (501(c)3) that administers and coordinates the U.S. voluntary standardization and conformity assessment system. The Institute's mission is to enhance both the global competitiveness of U.S. business and the U.S. quality of life by promoting and facilitating voluntary consensus standards and conformity assessment systems, and safeguarding their integrity.

http://www.ansi.org/

from air pollution control or air quality district permitting requirements by CARB. In addition, this certification qualifies the Company's products for preferential rate treatment by the California Public Utilities Commission (CPUC) such as the elimination of exit fees and standby charges for customer electric generation.

FCE was also awarded $67 million in new federal funding to continue their research in innovative fuel cell technologies, to make them more efficient and cost-effective. (For more information please see the NETL techline dated April 23, 2003 at http://www.netl.doe.gov/publications/press/2003/tl_fuelcell_seca2sel.html) They plan to unveil two more fuel cells in Los Angeles: one at Terminal Island that will operate on anaerobic digester gas and one in downtown Los Angeles that is to be determined.

FCE has direct fuel cell units operating in the U.S., Germany, Spain, and Japan producing over 9 million kilowatt hours of electricity for customers at hospitals, schools, universities and other commercial and industrial sites.

Since 1976, the federal government has invested more than $200 million in this advanced energy technology. Fuel cells produce electricity with minimal emissions that reduce greenhouse gases and meet environmental goals. Fuel cells operate cleanly using natural gas or wastewater treatment digester gas without combustion, so they emit little or no pollution.

FCE and NETL are working together to develop innovative technologies for

fuel cell power plants that generate electricity from natural gas in the cleanest way possible. The cooperation between NETL and Fuel Cell Energy is just one example of a successful partnership between government and industry striving to achieve the same goal: to secure a cleaner, more efficient energy future for the U.S.

For more information, please visit FuelCell Energy's website at: http://www.fce.com

For further details on this partnership, please contact Mark Williams, Product Manager, Fuel Cells, at Mark C.Williams@NETL.DOE.GOV or Norm Holcombe, Project Manager, Gas Power Projects at: NHOLCO@netl.doe.gov

California Rule 21 certification standard

California is one of the first states to have adopted a standard practice for the interconnection of Distributed Energy Resource (DER) devices to the electric grid. In October 1999, the California Public Utilities Commission (CPUC) issued an order instituting a new DER rulemaking (99-10-025) to address interconnection standards. This rulemaking progressed into the rewriting of Rule 21, part of each investor-owned utility's tariff, by a working committee including representatives from the California Energy Commission and the state's electric utilities. The new version of Rule 21 specifies standard interconnection, operating, and metering requirements for DER generators.

http://www.energy.ca.gov/distgen/

The California Air Resources Board (CARB)

The California Air Resources Board is a part of the California Environmental Protection Agency, an organization which reports directly to the Governor's Office in the Executive Branch of California State Government. The Mission of the California Air Resources Board is to promote and protect public health, welfare and ecological resources through the effective and efficient reduction of air pollutants while recognizing and considering the effects on the economy of the state.

http://www.arb.ca.gov/

Successful Demonstration of Mobile Leak Detector

In the near future utility workers using a mobile detector will be able to remotely detect natural gas leaks from distances of up to 30 feet. Physical Sciences Inc. (PSI), with funding from the National Energy Technology Laboratory, under the Natural Gas Delivery Reliability Program, has taken the first steps to develop and demonstrate a low cost, lightweight, mobile sensor for remote detection of natural gas leaks in distribution and transmission pipelines.

PSI conducted a successful test of its mobile detector at their research facilities in Andover, Massachusetts, on July 17, 2003. PSI's prototype mobile leak detector successfully detected the presence of natural gas in both indoor and outdoor environments. The test proved the capability of the detector to sense natural gas leaks from a distance of up to 30 feet from a vehicle moving at speeds up to 20 miles per hour.

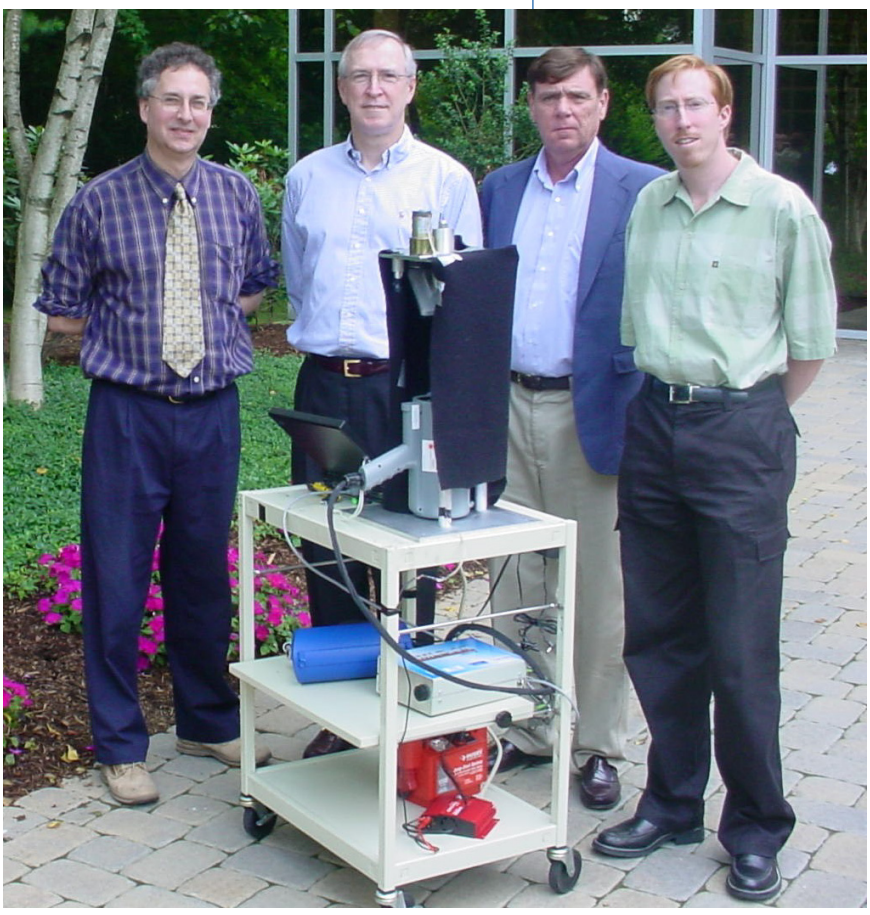
This technology will be capable of quantifying and distinguishing natural gas pipeline leaks from other hydrocarbon leaks or from ambient methane sources.

Further work will concentrate on mounting the detector on a utility service vehicle and demonstrating the mobile detection of natural gas leaks from an operating distribution pipeline. The

ability to reliably detect, and ultimately eliminate natural gas leaks in the pipeline infrastructure will further increase the integrity, operational reliability and safety of the U.S. natural gas delivery system.

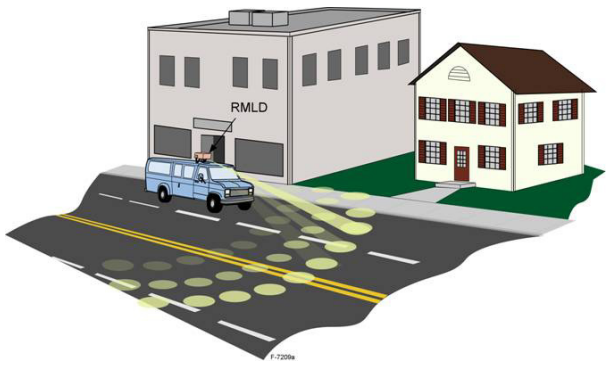
For further details on this project, please contact Magda Rivera, Project Manager, at Magda.Rivera@netl.doe.gov

From left to right: Mickey Frish (PSI), Rodney Anderson (NETL), Dan Driscoll (NETL), and Richard Wainner (PSI). Photo courtesy of Physical Sciences, Inc.



Benefits of mobile natural gas leak detector:

- Greater flexibility: van-mounted and removable portable unit will improve survey operations including hard to reach areas.
- Allow for an operator to perform rapid survey from a moving platform (driving at speeds of 20 mph with a 30 foot coverage) Allows for an operator to routinely monitor for leaking gas while doing other duties.
- Operators can check inside buildings or confined spaces from outside via a closed window or access.
- Estimates show productivity savings from 20%-40% for the average size utility.



Mobile sensor for remote detection of natural gas leaks. Unit mounted on truck scanning the street. Image courtesy of Physical Sciences, Inc.

HiTEC Helping Achieve FutureGen Goals

Research being conducted at the High Temperature Electrochemistry Center (HiTEC) at the Montana State University is now focused on crosscutting, multidisciplinary research that supports the Office of Fossil Energy's FutureGen Initiative.

FutureGen aims to improve efficiency and minimize environmental consequences of electrical power generation from fossil fuels, by combining electricity generation and hydrogen production with carbon sequestration for the virtual elimination of harmful emissions, including greenhouse gases.

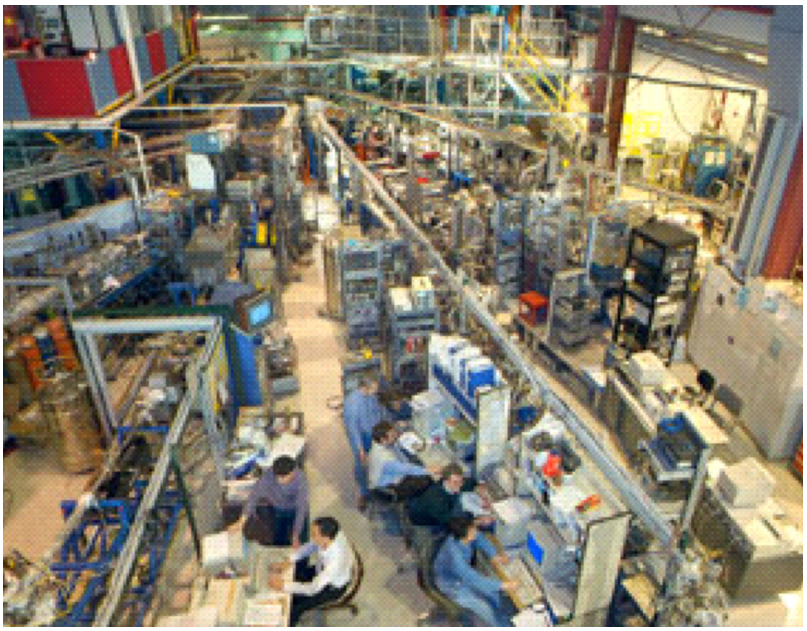
HiTEC established a satellite research center at the Montana State University in 2002, to address research topics such as: energy conversion, hydrogen production, gas separation and purification, electrolysis, energy storage, emissions reduction, thermoelectrics, sensors, and low-cost materials processing technologies. Specific research is being conducted on electrochemical processes at buried interfaces, the deposition and performance of multilayer thin film ceramic structures, managing electrical transients in fuel cell systems, and electrical properties of conducting ceramics.

Unique research facilities are being created and equipped with advanced diagnostic probes to support fundamental studies relevant to fossil fuel utilization. This collaborative effort is managed by the National Energy Technology Laboratory (NETL) and the Pacific Northwest National Laboratory (PNNL) with the core research activities being conducted at the PNNL Environmental Molecular Science Laboratory.

Reaching technical goals set by the Office of Fossil Energy includes establishing collaborative research in high temperature electrochemistry with universities, industry, and other national laboratories. Collaborative research has been established with the University of Utah, concentrating on the fundamentals of oxygen reduction at the cathode/electrolyte interface of a fuel cell.

FutureGen

Research conducted through HiTEC will be used on the FutureGen test platform. FutureGen is a $1 billion venture to build a prototype of the world's first fossil fuel power plant that combines electricity and hydrogen production with carbon sequestration technologies for the virtual elimination of harmful emissions, including greenhouse gases.



Montana State University's beamline at the National Synchrotron Light Source, includes capabilities for X-ray absorption spectroscopy, soft x-ray magnetic circular dichroism, and soft x-ray resonant magnetic scattering. These techniques are useful in probing the structure and chemistry of buried interfaces in solid oxide fuel cells. Courtesy of PNNL.

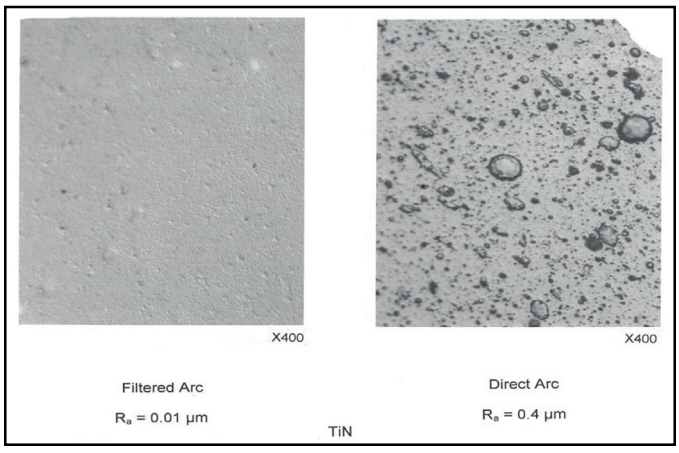
Research progress made in four selected areas is summarized below, conducted in collaboration with Montana State University and the University of Utah:

1. *Study of Buried Interfaces in Fuel Cell Structures.* Using polarization-dependent x-ray absorption spectroscopy, Professor Y. U. Idzerda (Department of Physics, Montana State University) discovered that the oxidation state of manganese in the cathode changes in response to interfacial stresses. Such chemical variations are important in limiting the rate of oxygen reduction, and in turn affect fuel cell performance.
2. *Development of Corrosion-Resistant Layers on Solid Oxide Fuel Cell Interconnects.* Professors R. J. Smith, R. Avci, M. Diebert, and J. Sears (Montana State University), in collaboration with V. Gorokhovsky (ARCOMAC), B. C. Roose (American Eagle Instruments), D. S. Gelles and S. Thevuthasan (PNNL) are using unique filtered-arc plasma deposition facilities to create multilayer thin film structures that show promise in corrosion protection at high temperature.
3. *Determination of Cathodic Polarization in Solid Oxide Fuel Cells Using Patterned Electrodes.* R. Radhakrishnan, Y. Jiang, and A. V. Virkar (University of Utah), in collaboration with O. A. Marina and S. C. Singhal (PNNL) have used patterned microelectrodes as a means of separating intrinsic electrocatalytic activity from microstructural effects in the fundamental study of oxygen reduction at the cathode-electrolyte interface of a solid oxide fuel cell.
4. *Reversible Solid Oxide Fuel Cells.* During off-peak hours, it may be advantageous to run a solid oxide fuel cell "in reverse," thereby producing hydrogen fuel by hydrolysis that could be used in a fuel cell at a later time.

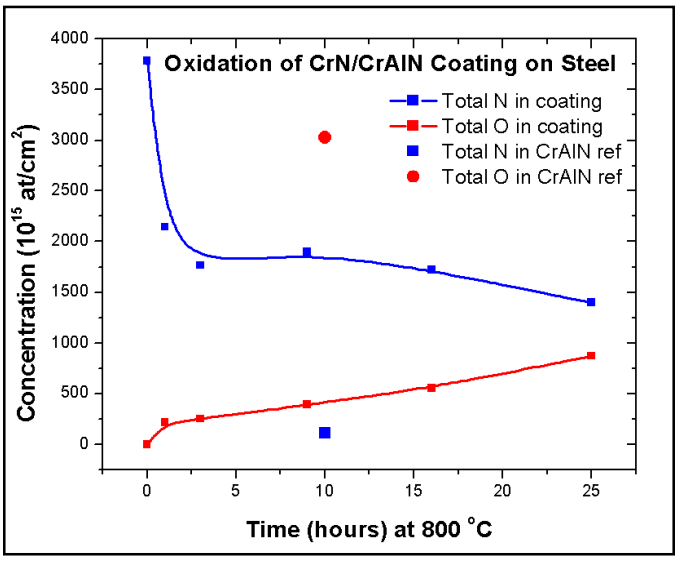
Because the efficiency of a reversible solid oxide fuel cell is closely related to losses associated with electrodes, efforts are underway at PNNL to improve electrode performance in both fuel cell and electrolyzer modes, led by Dr. O. A. Marina.

Additional satellite research centers at other universities are planned, focusing on topical areas where new scientific knowledge and innovations are necessary to overcome the technical challenges addressed by the FutureGen Initiative.

For further details on HiTEC, please contact Mark Williams, Product Manager, Fuel Cells, at Mark C.Williams@NETL.DOE.GOV



Comparison of plasma-deposited thin films of titanium nitride with and without filtering. Courtesy of PNNL.



Oxygen uptake in a multilayer CrN/AlN coating on ferritic stainless steel, measured by nuclear reaction analysis, versus time of exposure to air at 800°C. Slow growth of an oxide film is attributed to corrosion resistance afforded by the multilayer structure, consisting of individual layers only a few nanometers in thickness. Courtesy of PNNL.

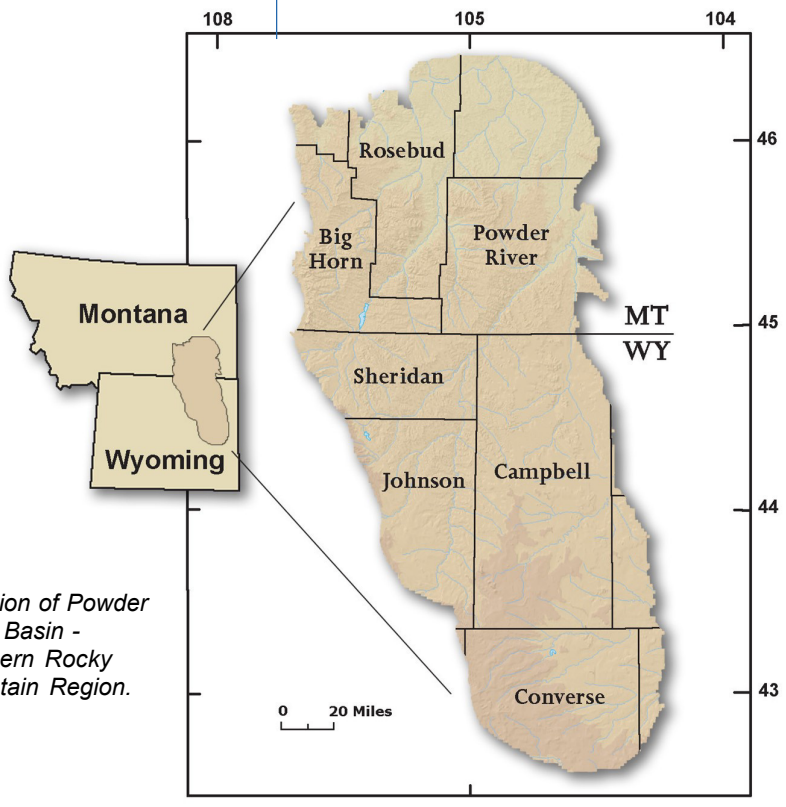
Impacts of Multi-Seam Completion on Power River Basin Coal Bed Methane

Powder River Basin

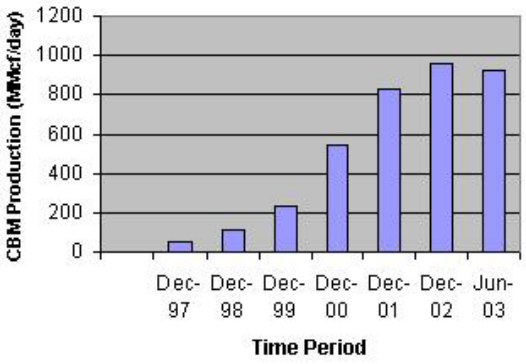
During the past several years, the most active natural gas play in the United States has been development of coalbed methane (CBM) in the Powder River Basin located in NE Wyoming and SE Montana. More than 11,000 wells are producing nearly 1 billion cubic feet per day (Bcf/d) of methane in addition to 1.5 million barrels of water per day (bbls/d).

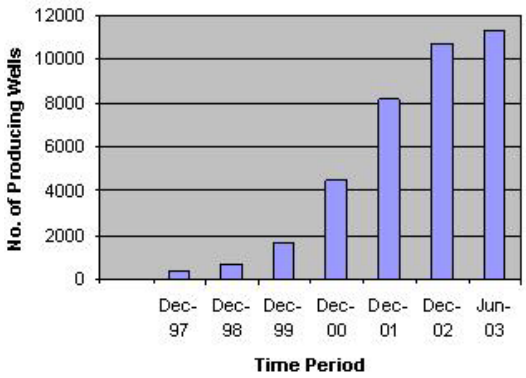
Building on an earlier analysis of natural gas (coalbed methane) development in the Powder River Basin, the U.S. Department of Energy (Office of Fossil Energy and National Energy Technology Laboratory) has released a new study detailing the potential benefits of multi-seam completions in the basin. The analysis, prepared by Advanced Resources International, Inc. (ARI), assesses the numerous sequences of thin coal seams that underlie major portions of the basin. Much of the play still to be developed is part of the federal mineral estate so governments at all levels have a significant stake in maximizing CBM production.

The Powder River Basin is located in northeastern Wyoming and southeastern Montana, and encompasses about 12,000 square miles. As of May 2003, the Powder River Basin produced nearly 1 billion cubic feet (Bcf) per day of natural gas and 1.5 million (MM) barrels of water from11,200 wells. Thus far, development has generally targeted the shallow, easy-to-reach thick coal seams along the eastern edge of the basin. However, as geologically more favorable areas are depleted, development has moved and will continue toward the deeper and somewhat thinner coals in the central and northern portions of the basin. Whenever the natural gas contained in these thin (<20 ft. thick) coals is considered in the context of recoverable resources, the volume of technically recoverable CBM significantly increases. Equally important, development/adaptation and widespread application of MSC technology is expected to significantly improve the economics of coalbed methane development in the basin.



Location of Powder River Basin - Northern Rocky Mountain Region.



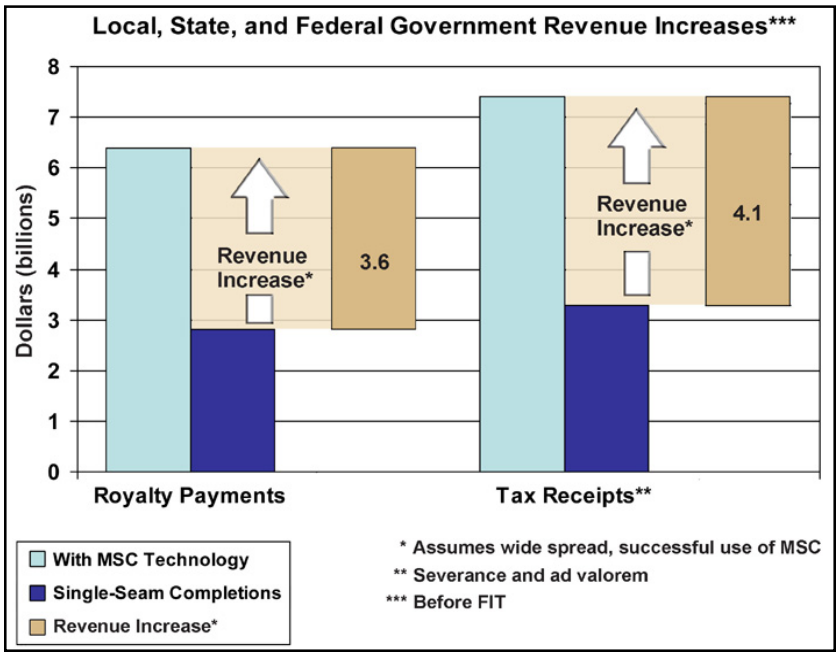


Operators in the Powder River Basin have long recognized the potential utility of multi-seam completions, and a handful of operators have tried the technique. Unfortunately, due to the unique geologic and reservoir properties of the coals in the Power River Basin—shallow, under-pressured, low-rank (low strength) coals surrounded by water-bearing aquifers—the application of MSC technology has been largely unsuccessful. Any successful technique must overcome the operational difficulties caused by sloughing shales and cement/fluid induced damage to the well-developed, highly permeable cleat system. Several operators in the basin have expressed the need for MSC advancements and have indicated a willingness to participate in a potential consortia-type technology development and demonstration program.

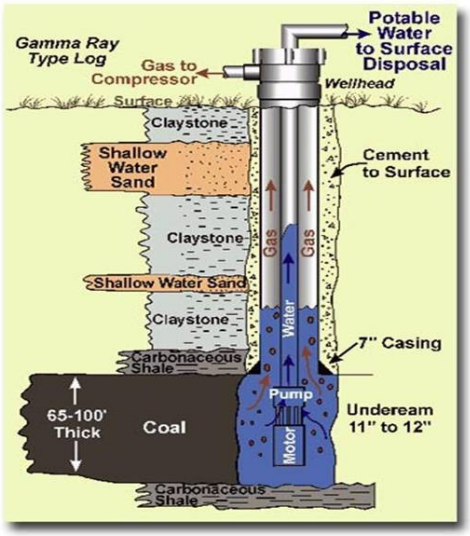
Objectives of the MSC study were to provide: (1) an estimate of how much additional CBM resource would become accessible and technically recoverable, compared to the current practice of drilling one well to drain a single coal seam; (2) a determination of whether there would economic benefits associated with MSC technology utilization (assuming its widespread, successful application) and quantify the gains; and (3) a brief examination of why past attempts by Powder River Basin CBM operators to use MSC technology have resulted in limited production improvements.

Assuming widespread, successful application of MSC technology, the revised outlook for coalbed methane in the Powder River Basin is as follows:

- The gas in-place in the Powder River Basin, both including thick and thin (< 20 ft.) coal seams, is estimated at 75 trillion cubic feet (Tcf).
- The technically recoverable coalbed methane resource in the Powder River Basin is estimated at 50 Tcf.
- The economically recoverable coalbed methane resource is estimated to range from 24 to 38 Tcf, assuming $3.50/Mcf at Henry Hub and two basis differential scenarios. In both scenarios, the volume of economically recoverable coalbed methane increases by 21 Tcf (vs. resource development via single-seam well completion methods).
- Federal and state revenues would significantly increase (using the declining basis differential scenario): Royalty payments are estimated to increase by $3.6 billion; and tax (severance and



Potential Economic Benefits Associated with MSC.

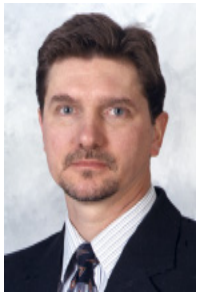


Typical Single-Seam Well Completion (Open Hole). Courtesy of L. Cook.

ad valorem) receipts are estimated to increase by $4.1 billion.

- MSC technology seems essential for developing the CBM resource in Montana and on Native American lands—areas that contain an abundance of natural gas in thinner coal seams.

MSC technology can help improve the outlook for coalbed methane in the Power River Basin by increasing reserves-per-well and decreasing unit costs. Successful adaptation of the technology and its widespread use are clearly part of an overall solution to more efficiently produce the resource, as are increased market access and advanced, lower-cost produced water management strategies.



The report and further information on this topic can also be obtained from the NETL website at www.netl.doe.gov.

For further details on this project, contact John R. Duda, Senior Analyst, at John.Duda@netl.doe.gov

SCNG Newsletter is a periodic publication of the U. S. Department of Energy (DOE), National Energy Technology Laboratory (NETL), Strategic Center for Natural Gas (SCNG).

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SCNG Events

November 3-6, 2003

2003 Fuel Cell Seminar
Fontainebleau Hilton Hotel
Miami Beach, Florida

The Fuel Cell Seminar is now an annual event, and the theme for 2003 is Fuel Cells for Secure, Sustainable Energy. The Fuel Cell Seminar is the premier international meeting for the fuel cell industry offering the largest number of technical papers, the most exhibits, and the best coverage of the latest technical advanced in the field. It encompasses sessions the discuss progress in four main areas: utility, residential, vehicle and portable, and discusses challenges in costs, fuels, storage, reliability, lifetime and adoptability. Fuel Cell Seminar exhibitors and sponsors represent the latest in leading research and development—both domestically and abroad.

February 8-11, 2004

Natural Gas Technologies II-Ingenuity & Innovation
Pointe South Mountain Resort
Phoenix, Arizona

An opportunity to join natural gas and energy industry leaders, technology solution providers, government officials and policy makers in an information exchange on the latest natural gas technology achievements and the policy and regulatory issues that face the natural gas industry.

For more information about these and other upcoming events, log on to SCNG's website and click on "Events." www.netl.doe.gov/scng